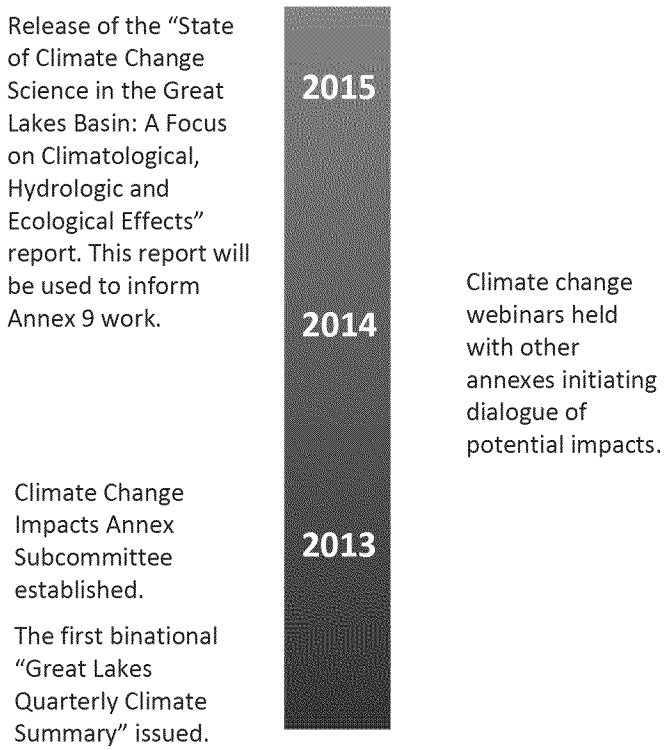
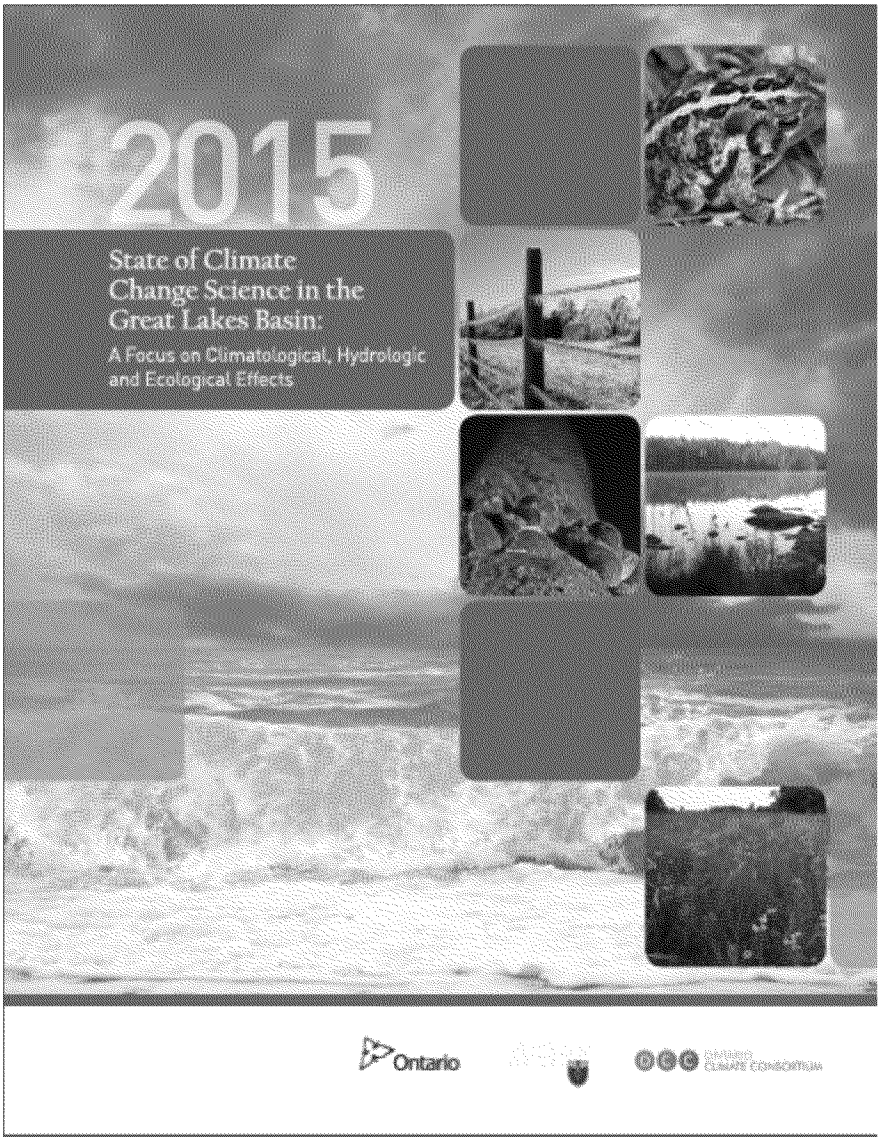
CLIMATE CHANGE IMPACTS ANNEX
PROGRESS REPORT OF THE PARTIES CHAPTER

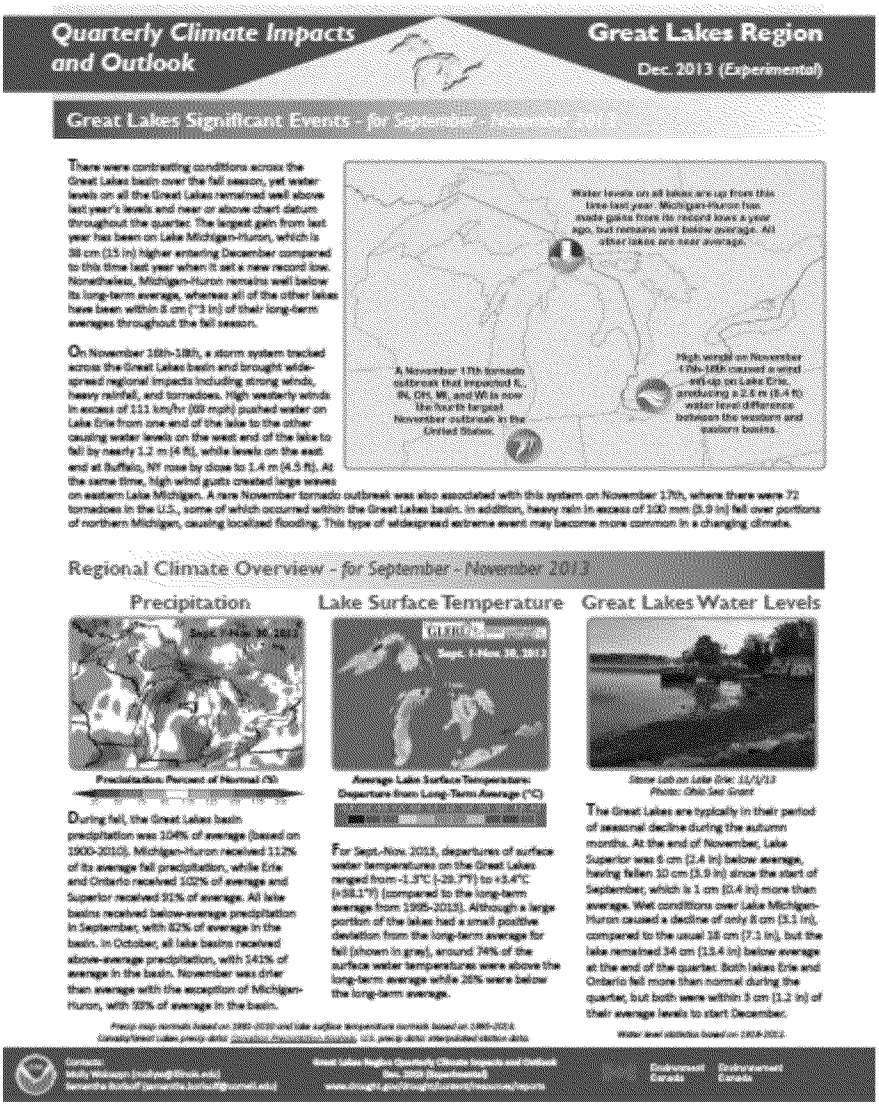
OVERVIEW

Recognizing that climate change has an impact on the quality of Waters of the Great Lakes, Canada and the United States incorporated a new annex in the 2012 GLWQA to address this issue, through which both governments commit to coordinate efforts to identify, quantify, understand, and predict the climate change impacts on the water quality of the Great Lakes and to share information broadly with Great Lakes resource managers to proactively address those impacts. A key activity of this annex in the first three years was a synthesis of available science on the observed and projected impacts of climate change in the Great Lakes Basin.

PROGRESS TOWARD MEETING GLWQA COMMITMENTS




2015
State of Climate Change Science in the Great Lakes Basin:
A Focus on Climatological, Hydrologic and Ecological Effects
Ontario



This Annexes' implementation is supported by the Climate Change Impacts Annex Subcommittee, co-led by Environment and Climate Change Canada and the National Oceanic and Atmospheric Administration. Organizations on the subcommittee include: [insert logos]

BINATIONAL ACTIONS TAKEN FOR KEY COMMITMENTS

Coordinate binational climate change science activities (including monitoring, modeling and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of the Waters of the Great Lakes and to achieve the objectives of this Agreement.

- In June 2013, Canada and the United States initiated the development of the first

binational quarterly newsletter focusing on climate impacts and outlooks for the Great Lakes region. The Great Lakes Climate Quarterly issues (www.binational.net/category/a9/qcio-btsc) provide a quick and easy-to-understand binational overview of the latest season's weather and water level conditions, weather and water level-related impacts, and an outlook for the upcoming quarter. These Great Lakes Climate Quarterlies are produced by Canadian and United States experts for use by managers and practitioners at federal, state, provincial, regional, and local scales as well as stakeholders and the general public.

- A series of webinars were conducted in 2014 to present information on the best available peer-reviewed climate change science in the Great Lakes to Annex Subcommittees, as well as other interested parties such as the Council for Great Lakes Industries. Webinars were provided specifically to: 1) enhance broad understanding of climate information; 2) to discuss the type of climate change information required by other Annex Subcommittees to support their activities; 3) to help focus the work of the Climate Change Impacts Annex Subcommittee in providing more tailored climate change information.

- In December 2015, a "State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrologic and Ecological Effects" report was released, which synthesizes the state of climate change impacts in the Great Lakes basin and identifies key knowledge gaps. The Executive Summary and further information is available at [insert binational.net link]. The 2015 State of Climate Change Science in the Great Lakes Basin report, and the companion database of all the literature reviewed for the report, were developed by the Ontario Climate Consortium, the Ontario Ministry of Natural Resources and Forestry, and McMaster University, with support from Department of Fisheries and Oceans Canada and Environment and Climate Change Canada, and in consultation with Climate Change Impacts Annex Subcommittee. The report supports various commitments under the Climate Change Impacts Annex and will be used for further discussions with Annex Co-Leads and their Subcommittees and inform future work of the Climate Change Impacts Annex Subcommittee.

Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts.

- A growing ensemble of in situ measurements – including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms – are being deployed through an ongoing binational collaboration known as the Great Lakes Evaporation Network. The Network is helping to reduce uncertainties in the Great Lakes water balance, providing a more robust basis for short- and long-term projections of [...], and filling a significant gap in measurements, including evaporation and water temperatures, and related meteorological data. The Network is supported through a consortium of researchers from Environment and Climate Change Canada and the National Oceanic and Atmospheric Administration, the University of Michigan, Northern Michigan University, the University of Colorado, Limno-Tech and the Great Lakes Observing System.

DOMESTIC ACTIONS TAKEN

Develop and improve regional scale climate models to predict climate change in the Great Lakes Basin Ecosystem at appropriate temporal and spatial scales.

Link the projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes to better understand and predict the climate change impacts on the quality of the Waters of the Great Lakes.

- Canada continues to support the development of coupled atmospheric-land-ocean models for the Great Lakes-St. Lawrence River system that can be integrated with Regional Climate models to evaluate the hydrometeorological impacts of climate change.

- A coordinated evaluation of the impacts of climate change on the levels and flows of the St. Lawrence River between 2041-2070 and 1971-1999 is being undertaken through a collaborative of agencies including Fisheries and Oceans Canada, Hydro-Quebec, Direction de l'expertise hydrique of Quebec, OURANOS and Environment and Climate Change Canada. Climate change will modify the flow of water into the St. Lawrence River (from Lake Ontario, the Ottawa River, and tributaries) and the level of the Great Lakes. These two factors will lead to changes in both the average and extreme levels in the St. Lawrence River. The anticipated impacts include erosion or deposition along the river banks, navigation impacts, and impacts to drinking water intakes. A major focus of this project is improving the analyses of the routing of Ottawa River flows so that Great Lakes and St. Lawrence River models can be linked.

Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts.

- Environment and Climate Change Canada collects data from a network of approximately 1300 surface weather and climate observing sites across the country. These sites include weather stations owned by Environment and Climate Change Canada, NAV CANADA, National Defence, along with volunteer climate stations. The majority of these sites are automated observing platforms which report year round, 7 days a week, 24 hours a day. The Water Survey of Canada is the national authority responsible for the collection, interpretation and dissemination of standardized water resource data and information in Canada. In partnership with the Province of Ontario, the Water Survey of Canada operates approximately 440 active hydrometric gauges in the Canadian portion of the Great Lakes-St. Lawrence River Basin. The Science and Technology Branch of Environment and Climate Change Canada supports the operation of three evaporation stations at Stannard Rock on Lake Superior, Long Point on Lake Erie and Simcoe Island on Lake Ontario as part of the Great Lakes Evaporation Network.

- Multiple methods and estimates of Great Lakes runoff are now available from various federal agencies in Canada and the United States and a comprehensive evaluation and coordination

of runoff estimates is necessary. The Great Lakes Runoff Inter-comparison Project was initiated as a binational collaboration aimed at assessing a variety of models currently used (or that could readily be adapted) to simulate basin-scale runoff to the Great Lakes. The Great Lakes Runoff Inter-comparison Project for Lake Ontario was initiated by Environment and Climate Change Canadian in 2013. The project compared different hydrologic models in their ability to estimate Lake Ontario's direct incoming runoff. The results highlight the different models' weaknesses and strengths, in order to assess which model to use as a function of the targeted application and experiment settings, with the more general goal to improve Lake Ontario's runoff simulation by identifying and fixing some of the model weaknesses.

Develop and improve analytical tools to understand and predict the impacts, and risks to, and the vulnerabilities of, the quality of the Waters of the Great Lakes from anticipated climate change impacts.

- The Canadian Precipitation Analysis is an operational near real-time gridded precipitation product from Environment and Climate Change Canada available since April 2011 for North America. The Canadian Precipitation Analysis is highly regarded due to its unique capability of capturing some of the precipitation features that are specific to the Great Lakes-St. Lawrence River region, in particular the effects that the lakes have on the precipitation patterns, something that is very difficult to measure? with the existing precipitation gauging network. A project was initiated in 2015 to provide the foundation for extending the Canadian Precipitation Analysis back to 1983.

Develop and improve regional scale climate models to predict climate change in the Great Lakes Basin Ecosystem at appropriate temporal and spatial scales.

Link the projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes to better understand and predict the climate change impacts on the quality of the Waters of the Great Lakes.

- The National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Lab (GLERL) brought together several different modeling and observational approaches to study climate change in the Great Lakes basin. The modeling activity consisted of further development and application, specifically for our lake-dominated region, of three coupled atmosphere-lake-land regional climate models: the Coupled Hydrosphere-Atmosphere Research Model (CHARM, based on the Regional Atmospheric Modeling System, RAMS) at the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory, the Regional Climate Model version 4 (RegCM4) at the University of Wisconsin, and the Weather Research and Forecasting Model (WRF) at the University of Maryland; along with development and testing of a version of the Finite Volume Coastal Ocean Model (FVCOM) with enhancements for

simulation of ice (FVCOM-Ice) and lower trophic level ecology in the form of a nutrient-phytoplankton-zooplankton-detritus (NPZD) model component.

Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts.

- In 2013, the Lake Superior National Estuarine Research Reserve established a new Sentinel Site located in Pokegama Bay, Lake Superior. With funding support from the National Oceanic and Atmospheric Administration, this Sentinel Site included weather/meteorological station, water quality sonde, surface elevation tables, permanent vegetation transects, geodetic vertical referencing benchmarks, and an acoustic doppler current profiler installation. This site is now recording monthly water quality sampling for nutrients and chlorophyll. The primary goal is to understand sediment movement and the consequence of sediment movement to marsh sustainably under the expectation of the increased frequency and intensity of storm events.

- The National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Lab has been exploring the relationships between ice cover, lake thermal structure, and regional climate for over 30 years through development, maintenance, and analysis of historical model simulations and observations of ice cover, surface water temperature, and other variables. Weekly ice cover imaging products produced by the Canadian Ice Service started in 1973. Beginning in 1989, the United States National Ice Center produced Great Lakes ice cover charts that combined both Canadian and United States agency satellite imagery. These products are available at the Great Lakes Environmental Research Lab through the Coastwatch program (www.coastwatch.glerl.noaa.gov), a nationwide National Oceanic and Atmospheric Administration program within which the Great Lakes Environmental Research Lab functions as the Great Lakes regional node.

- Currently, there is year-round monitoring infrastructure dedicated to understanding off-shore processes that impact Great Lakes ecosystem health. Beginning in Fiscal Year 2015, the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Lab (with funding support from the National Oceanic and Atmospheric Administration's Coastal Storms Program) is seeking to fill these data gaps through a two-phased approach. First, the team will deploy and manage data from vessel- and buoy-based sensors to improve understanding of over-water meteorology, evaporation, and water temperature in the Great Lakes. Second, the project will also focus on data analysis, system validation, and model assimilation to improve access to and understanding of the acquired data.

Develop and improve analytical tools to understand and predict the impacts, and risks to, and the vulnerabilities of, the quality of the Waters of the Great Lakes from anticipated climate change impacts.

- The National Oceanic and Atmospheric Administration's Office for Coastal Management developed and released the Lake Level Viewer (www.coast.noaa.gov/llv) for the United States portion of the Great Lakes basin in 2014. This tool helps users visualize lake level changes that range from six feet above to six feet below historical long-term average water levels in the Great Lakes,

along with potential shoreline and coastal impacts. Communities can use this information to determine what preparations make the most sense in planning for water level change scenarios. Preparations might include zoning restrictions, infrastructure improvements, and habitat conservation. As a result of this work and product delivery, Digital Elevation Models for each lake basin and the associated topographic and bathymetric data are now available on The National Oceanic and Atmospheric Administration's Digital Coast (https://coast.noaa.gov/digitalcoast/).

- The National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Lab developed and released a basin wide Water Level Dashboard in 2014 (www.glerl.noaa.gov/data/dashboard/GLHCD.html). The Dashboard is a dynamic graphical interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes. This interface also reflects relationships between hydrology, climate, and water level fluctuations in the Great Lakes.

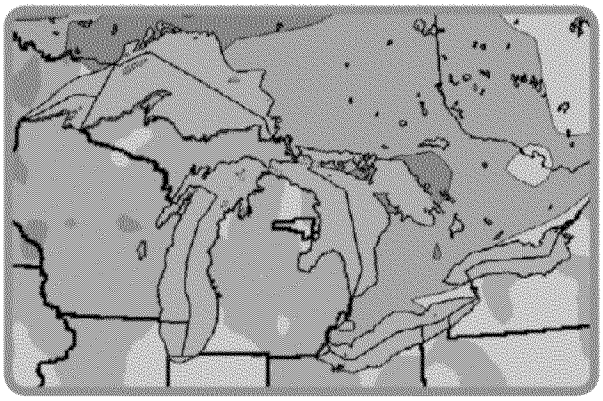
Coordinate binational climate change science activities (including monitoring, modeling and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of the Waters of the Great Lakes and to achieve the objectives of this Agreement.

- The National Oceanic and Atmospheric Administration's National Center for Environmental Information produces an annual "State of the Climate" report (www.ncdc.noaa.gov/sotc). This report provides a collection of monthly summaries recapping climate-related occurrences on both a global and national scale.

- The National Park Service released a Climate Change Scenario Planning Workshop Summary. This report summarizes outcomes from a two - day scenario workshop for Apostle Islands National Lakeshore, Wisconsin. The primary objective of the session was to help senior leadership make management and planning decisions based on up - to - date climate science and assessments of future uncertainty. The session was also designed to assess the effectiveness of using regional - level climate science to craft local scenarios; and to provide an opportunity for participants to better understand how scenarios can be used.

Possible graphics:

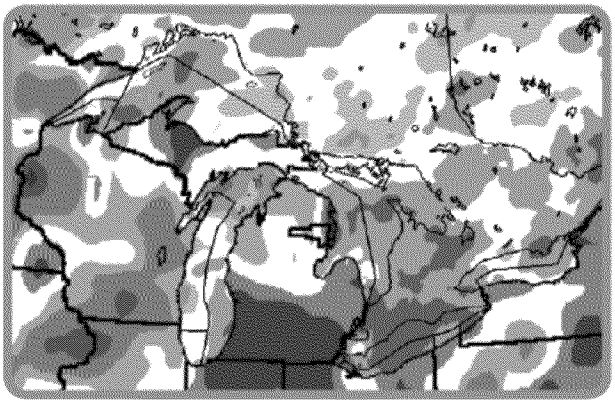
Sources: GL Climate Outlook – Fall 2015



Sept-Nov 2015 Air Temp:
Departure from Normal

°C -5 -4 -3 -2 -1 -0.5 0.5 1 2 3 4 5

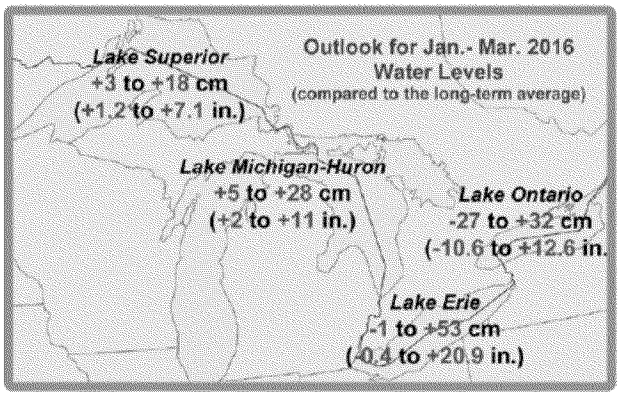
°F -9 -7.2 -5.4 -3.6 -1.8 -0.9 0.9 1.8 3.6 5.4 7.2 9



Sept-Nov 2015 Precip:
Percent of Normal (%)

25 50 75 90 110 125 150 175 200

Lake Level Outlook



Potential range for water levels for Jan-Mar 2016 compared to the long-term average (1918-2014).